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RESEARCH ARTICLE

A NEW FIELD TEST WITH DIFFERENT FLOORS TO MEASURE DYNAMIC BALANCE AMONG PRESCHOOL CHILDREN

Zehra Güçhan Topcu[1], Hatice Hacıküçük[1], Erdoğan Çetintaş[1], Hayriye Tomaç[1], Tuğba Obuz[1], Nazan Şeker[1], Levent Eker[1]

[1] Eastern Mediterranean University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Famagusta, Cyprus

ORCID: Z.G.T. 0000-0001-8587 -7407; H.H. 0000-0002-9212-8049, E.Ç. 0000-0002-3228-1455, H.T. 0000-0002-8245-9995, T.O. 0000-0001-9371-7964, N.Ş. 0000-0002-7320-8991, L.E. 0000-0001-7301-4073

Corresponding author: Zehra Güçhan Topcu, **E-mail:** zehraguchan@hotmail.com / zehra.guchan@emu.edu.tr
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ABSTRACT

Purpose: This study aimed to assess the test-retest reliability and inter-rater reliability of a newly designed balance test named the Paediatric Tandem Balance (PTB) test.
Material and Methods: 108 children (girls: 54, boys: 54) with a mean age of 4.08±0.78 were included in the study. Two raters measured the same children for inter-rater reliability, and the first rater retested the same children after two days for test-retest reliability. Time and sway numbers were recorded as the variables of the PTB test.
Results: The inter-rater reliability was good in both parameters of PTB which were duration (r=0.836) and number of sways (r=0.840). The test-retest reliability was good in both duration (r=0.727) and number of sways (r=0.705). The PTB test is a reliable test to measure dynamic balance in 3-5 years old children.
Conclusion: This test will bring a new point of view for tests of dynamic balance.

Keywords: balance, balance test, dynamic balance, postural control

INTRODUCTION

Balance supports the development of the motor systems of children as it is a prerequisite to learn and control fundamental motor skills in daily life (1,2). Static balance is defined as the ability to provide body balance in a specific location or position, whereas dynamic balance exists during the movement or execution of the movement (3). Both sensory and motor regions of the brain should give correct information to muscles which are the main active elements of body. When muscles obtain correct information from brain, they should arrange amount of their contractions in an adequate time interval (1,2). Postural control which needs visual, vestibular and somatosensory (e.g., plantar cutaneous, proprioception) input plays a fundamental role in the maintenance of balance (3,4). Cognition has an important role to perceive and integrate these sensory inputs in order to maintain balance so cognition is like a bridge from sensory to motor behaviour (5).

Both balance and some cognitive functions like attention are controlled by the same central region, the cerebellum (6). Thus, it may be stated that there is a relationship between balance and cognitive tasks and that many daily activities require a good balance control with cognitive skills (7). In addition, an increase in balance may contribute to some cognitive skills such as memory and spatial cognition (8). Lima et al. (9) also stated that there is a positive association between the dynamic balance and academic performance of children. Shortly, balance skills may affect attention, memory, spatial performance, and learning skills for academic performance.

Gallahue (1) states that babies detect their body parts and their movements with reflexes and rudimentary movements like crawling and walking during the first two years of life. The first form of rudimentary movements are immature, but babies get more experience with practices and start to develop postural reactions to keep in balance in these movements. Thus, until 2 years old, babies should gain balance in rudimentary movements. From 2 to 7 years old, children start to develop fundamental motor skills which are important movements for sport activities like running, jumping and hopping (1). The practices and experiences of these movements develop better balance in these movements until 7 years old. The late development of balance among children leads to the late and inadequate learning of complicated motor skills like running, jumping and climbing. This negatively affects the participation of children in athletics activities and causes more injuries (2). As a result, monitoring balance development and determining potential factors which may prevent this development is important in childhood (10).

Dynamic balance develops in a complicated way as it needs the integration of sensory systems and experience in motor learning (3,11). There are many tests used in clinical practice to measure dynamic balance (10,12-15). For example, in two systematic reviews of dynamic balance tests in children, fourteen tests were investigated, and among them, three tests, the Timed-Up and Go (TUG) test, Pediatric Balance Reach test and Pediatric Balance Scale, showed good reliability in children (10,15). In both reviews by Verbecque et al. (10,15), it was stated that standardisation is needed in the criteria of balance tests for children as children need motivation to follow directions and speed. Although balance is affected by many environmental factors, and the floor where a test is conducted is one of the most important factors among these, none of the existing tests has focused on this parameter (16). Particularly, the effects of the floor should be measured in children as their balance develops during growth, and it is a prerequisite for many motor skills as mentioned before; so, when this factor is added to measurements, it will increase the strength of analyses carried out on balance in

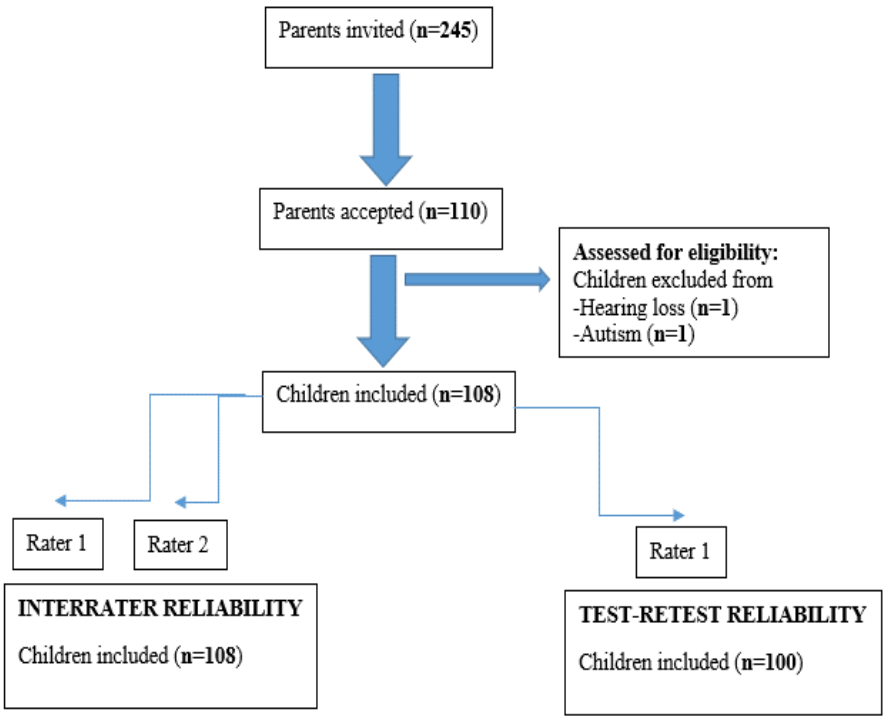

Figure 1. Flowchart of the reliability study

children (1,2,11). Moreover, in daily life, people need to improve balance reactions and protect their balance on many types of surfaces (such as snowy, wet, stony, hard, foam ground) (16).
As the first five years of life plays a critical role in the development of motor skills, the use of accurate tests which reflect performance as much as possible is required to see the actual level and progression that are aimed to be measured (17). Compared to laboratory tests, field tests present better options for the examiner as they are cost-effective, easy to administer and usually portable with minimal equipment. Although dynamic balance is important to adapt the body on different floors in mobile conditions, there is no field test to measure this balance involving variations of floor materials. The Paediatric Tandem Balance (PTB) test was designed with this aim, and it was hypothesised that this test would demonstrate reliability to measure dynamic balance in children.

MATERIAL AND METHODS

Study Design and Participants

Children living in Famagusta were included in this study. They were children registered to kindergartens of the city of Famagusta. According to the inclusion criteria, children who were 3-5 years old were included. H1 hypothesis = 0, H1 hypothesis = 0.3 and $\alpha = 0.05$, $\beta = 0.20$ were calculated for the sample size, and 84 people were obtained. The initial value was increased by 20% for the second assessment, resulting in 100 healthy children aged 3-5.
Children who had sensory loss which would prevent them from taking the test or understanding the explanations, had communication problems in understanding the test, orthopaedic, neurological, or mental problems were excluded from the study (Figure 1).
Age, sex, height and weight were firstly recorded. Then, the PTB test was applied to the children. Two raters used a stopwatch (Catiga CG-503) to record time. The test was firstly explained with short sentences that were the same for all children and then the raters showed the test practically. The tests were conducted in barefoot condition. The PTB test is explained below in details.

PTB Test

This test was designed by considering the need of testing dynamic balance on different surfaces. The standardization of this field test was challenging.

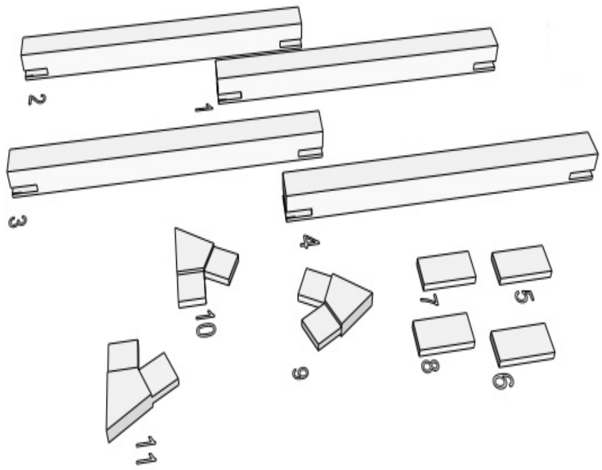

Figure 2. The pieces of the Paediatric Tandem Balance test platform. Numbers 1-4: Long pieces, Numbers 5-8: Straight connectors, Numbers 9-11: 60-degree angle connectors.

Tandem walking was chosen to standardize steps on the platform and the dimensions were arranged according to single foot. Then, the floors were chosen and connections were considered. In the end, 4 different floors with 4 different hardness grades (wood, hard sponge, soft sponge, and fibre) were created using four 100-cm-long, 8-cm-high and 8-cm-wide blocks (Figure 2, shapes 1-4). One piece was completely produced from wood material with 8 cm. Other three pieces have 4 cm wood bases and 4 cm different materials (as mentioned above sponge and fibre) on the wood base. All four long pieces of the PTB test platform were covered with same leather in the same color.
The platform could be brought to different shapes as a line or a square (Attachment 1). There were seven connector parts. Four straight connecters (Figure 2, shapes 5-8) were used to make various shapes like a square or a line. The other three connectors (Figure 2, shapes 9-11), which had a 60-degree angle, were used to make W and triangle shapes (Figure 2). Since we tried different shapes in the tests of some children before deciding the shape for testing and saw that the W shape had a clear start and end point, we decided to use the W shape (Figure 3). Moreover, this shape gave the message to the child that they were going to a new floor, so that planning about the floor could be done more easily, and the risk of falling was reduced in comparison to the use of other shapes. The ability to walk on this test platform was measured by time completion and sway numbers from platform. The W platform was assembled from the difficulty level easy

Table 1. Descriptive characteristics recorded in the PTB test

Variables	N	Range	Minimum	Maximum	Mean	Std. Deviation
RATER 1 - TIME (PTB) (sec.)	108	81.77	17.32	99.09	38.22	15.17
RATER 1 - SWAY NUMBER (PTB)	108	18	0	18	5.17	3.64
RATER 2 - TIME (PTB) (sec.)	108	94.18	11.08	95.26	35.18	13.06
RATER 2 - SWAY NUMBER (PTB)	108	18	0	18	5.08	3.49
RATER 1 SECOND ASSESSMENT - TIME (PTB) (sec.)	100	73.15	14.16	87.31	37.56	14.25
RATER 1 SECOND ASSESSMENT - SWAY NUMBER (PTB)	100	17.00	0	17.00	5.29	3.35

Figure 3. The Paediatric Tandem Balance Test and a child in the test.

to the level of hard. Hence, the child was asked to make a tandem walk in the following order: on wood, hard sponge (density=28 DNS), soft sponge (density=22 DNS), and fibre. The raters used the same commands and similar instructions to children since these would affect results. At first, the raters explained to the children how they would be assessed on the platform. The children were permitted to do any kind of tandem walk (full tandem, semi-tandem) and walk on only long pieces without touching the connectors of the peak points of the W-shape. Standing with any region of the heel of one foot touching the big toe of the other foot in front is defined as semi-tandem position, while standing with the heel of one foot in front of the fingers of other foot is full tandem (18).

For the starting position, the children were ready on the ground without any contact with the platform. Following the “START” command was given, they were asked to step onto the platform with their preferred leg and complete test platform carefully without swaying out of the platform. If they could not prevent to sway out, they would continue from the same point with stepping onto the platform back. The platform did not allow running as its base of support was narrow for running. When they complete the W shape, they were asked to change direction by going down from the platform to the ground and walk again to the starting location from the most difficult floor to the easiest. Words for motivation were not permitted before, during or after test.

First of all, the first walk was carried out as a practice for the children to learn the platform and understand what to do. In this first experience, the rater walked next to them to guide them and reassure them without any touching or holding (Figure 3). After this experience, the children were asked whether they understand the test and have any question about the test. Additionally, some children were curious about the platform, and the raters did not prevent them from touching the platform if they wanted to do so. Then, the next attempt was recorded for the test result. As soon as the children stepped onto the platform, timing was started, and when they returned to the point where they were standing before stepping on the platform, it was stopped. The duration was recorded in seconds. The numbers of sways of the children to the ground with any foot or both feet were counted without stopping the time recorded on the track. The durations and numbers of sways were recorded as the outcomes. After every child, the platform was cleaned as the covering material allowed easy hygiene. For the reliability of the PTB test, every included child was assessed three times. For inter-rater reliability, two raters (the second and third authors) assessed the children two times with at one-hour intervals on the same day. The order of the raters was randomly decided by tossing a coin and the raters were blind to each other's results.

The first rater (the second author) also assessed the same children after two days to measure test-retest reliability. The measurement results of the test were recorded as the first rater, the second rater and the second assessment of the first rater.

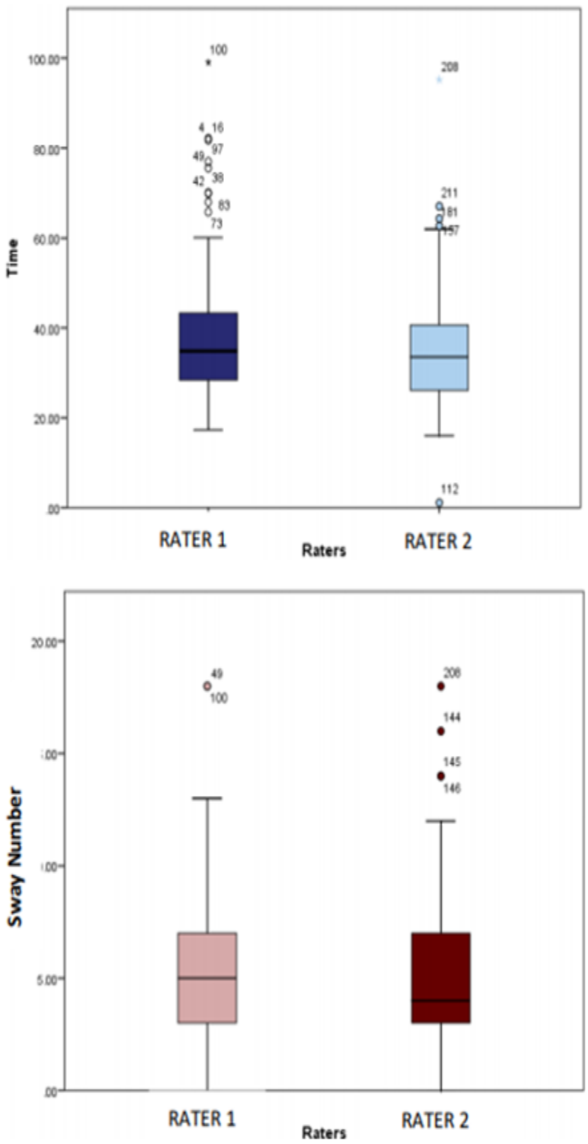

Figure 4. Distribution of the data for both raters with boxplot which indicates some points in terms of normality (Boxplot for inter-rater reliability)

Statistical Analysis

The data were analysed using the IBM Statistical Package for the Social Sciences (SPSS) 22.0. The categorical data are presented as percentages (%). The continuous data are presented as means and standard deviations. Since all variables were normally distributed, Pearson's correlation analysis was used (Table 1). The intraclass correlation coefficient (ICC) with two-way random effects was used to analyse test-retest and inter-rater reliability. Paired-samples t-test and Pearson's test were used to support the evidence about test-retest reliability. Bland-Altman plot analysis was used to evaluate the agreement between the values of the test and retest measurements.

Ethical Consideration

The study was approved by the Research and Publication Ethics Committee of Eastern Mediterranean University, in accordance with the Declaration of Helsinki (Decision Date: 24.05.2018, No: 2018/59-19). Informed consent, approved by the university's ethics committee, was taken from the parents of all children after explaining the aim and procedures of the study in detail. This study was also registered on ClinicalTrials.gov (NCT03777995).

RESULTS

Participation flow of the children

The parents of 245 children were invited to the study. The parents (n=110) who agreed for their children to participate in the study and their children (n=110), including 55 girls and 55 boys, were assessed. One child (girl) had hearing loss, and one child (boy) had autism, so they were excluded. A total of 108 children were tested on the first assessment day. Twenty-eight (25.9%) children were three years old, 43 (39.8%) were 4 years old, and 37 (34.3%) were 5 years old. Eight of the children did not attend the second assessment. So, the data of 100 children were used for the test-retest reliability analysis (Figure 1).

Demographic characteristics of the sample

The mean age of the children who were included in this study was 4.08±0.78 years. The mean height of the children was measured as 104.28±7.81 cm, and their mean weight was 18.35±3.44 kg. Their body mass index values were 16.77±1.75 kg/m2.

Descriptive findings obtained by the raters

Table 1 shows the descriptive statistics for the variables. A wide dispersion of the measurements was seen, which led to quite high standard deviation values especially for Rater 1-Time, Rater 2-Time, and rater 1 second assessment-Time as 15.17, 13.06, and 14.25, respectively. In relation to how the data for both raters were distributed, it was considered that boxplots can clearly explore such distributions and describe normality. Both measurements from both raters were quite similar, and the plot definitely not showing concrete evidence to be perfectly normal (Figure 4). We also plotted the first rater's score with the second assessment with respect to time and number of sways. This method was used to analyse test-retest reliability as well. The two assessments looked very much like each other as seen in Figure 5.

Test-retest reliability of the PTB test

An ICC model was established to analyse the intraclass correlation coefficient (ICC) calculations. Table 2 shows that there was a quite strong consistency level between the first and second assessments for the time measurements with a coefficient of 0.842 in a 95% CI (0.765 – 0.894). Additionally, there was high consistency between the first and second assessments of the sway numbers by the first rater with an ICC value of 0.826 in a 95% CI (0.742 – 0.883). The differences between repetitions and the relationship between differences and correlation values are shown in Table 3.

Another useful test involves drawing Bland-Altman plots. If the points on the Bland–Altman plot are all

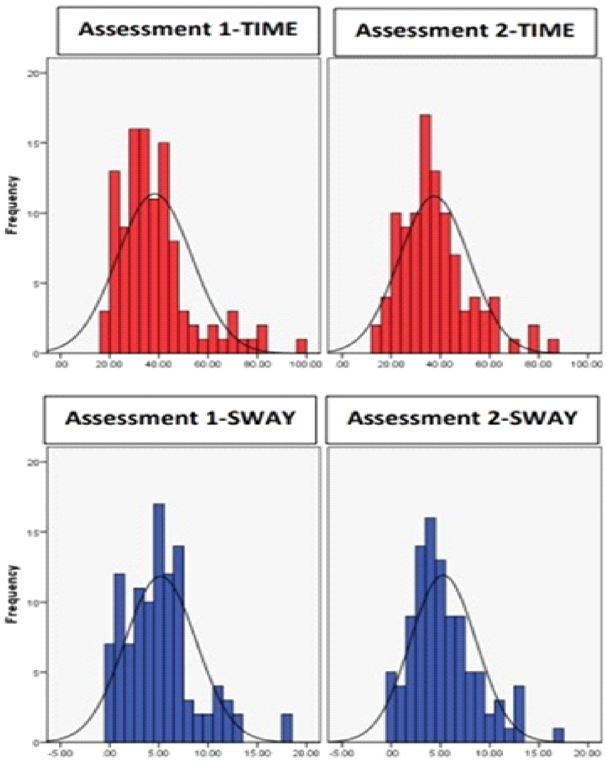

Figure 5. Plotting the first rater's first and second assessments to see the distribution in terms of time and sway numbers (plotting for test-retest reliability)

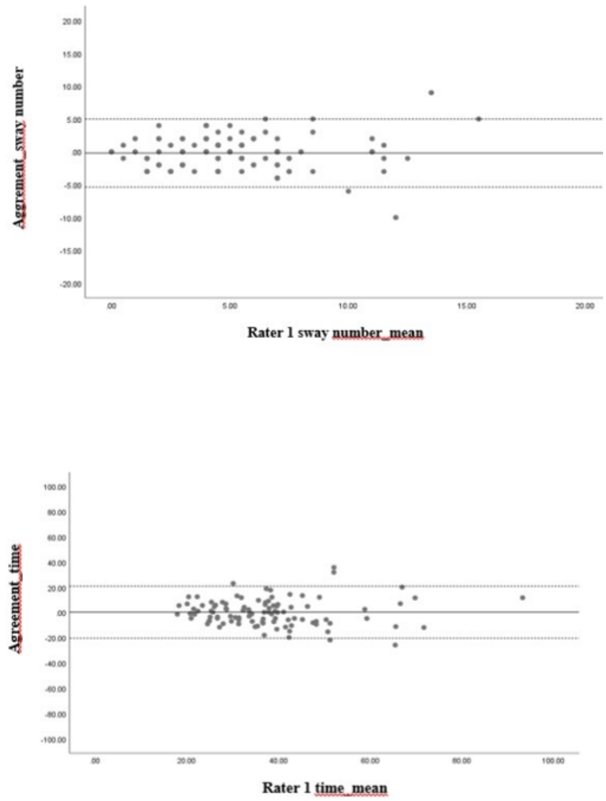

Figure 6. Bland-Altman plot analysis to see the level of agreement for the first and second day assessments

over the place, above and below zero, it means that there is no consistent bias in favour of one strategy over the other. It can be seen on the plot that there was consistency between the rater's first and second assessment measurements (Figure 6).

Inter-rater reliability of the PTB test

Inter-rater reliability of the measurements of both time and sway numbers was also analysed by determining the interclass correlation coefficient (ICC). The value of ICC in a 95% CI was 0.836 (0.760-0.888) for time, which indicated a strong agreement between the two raters. For the sway numbers, the ICC value in a 95% CI was recorded to be 0.840 (0.766 – 0.891). Accordingly, the method was determined to be reliable, and it could be used for overall assessments (Table 4).

DISCUSSION

tandem, full tandem) for balance. Thus, the PTB test included different somatosensory systems by reducing the base of support and visual input. As mentioned in the methods, all four pieces of the PTB test platform were covered with the same material and the same colour, so that the pieces would appear in the same from the outside, and the children needed more somatosensory feedback from the plantar region. The test limits the measurement in a variety of components of balance so it can be stated that this probably causes high reliability of the PTB test.

Visual feedback is reduced in many balance tests to investigate whether other sensory systems (e.g., proprioceptive, vestibular) can be used and integrated for postural control and balance (19). Existing tests usually use "closed eyes" while reducing the degree of this feedback. Thus, this new platform brings a new testing model for dynamic balance in terms of lowering visual input and varying the floor material. Visual input is completely non-existent when one's eyes are closed, whereas it is diminished in the PTB test because children experience the platform before the test and learn that its pieces have different hardness levels. Nevertheless, it does not provide the same amount of visual input as walking on floors with different appearances, for example, pink wood and blue sponge.

As the prevalence of measurement procedures of balance in children at the ages of 3-5 is low, the TUG test has been recommended more for this age group,

Table 2. Test-retest reliability testing using ICC

	Intraclass Correlation Coefficient			
	Intraclass Correlation	95% Confidence Interval Lower Bound	Upper Bound	
First & Second Assessments (Time)	0.842	0.765	0.894	0.000
First & Second Assessments (Sway number)	0.826	0.742	0.883	0.000

Table 3. Differences between repetitions and the relationship between differences and correlation values

	Mean ± SD	Correlation with first assessment	Sig	Correlation with second assessment	Sig
Difference between first and second assessments (time)	3.44±16.41	0.430	0.000	0.375	0.000
Difference between first and second assessments (sway number)	0.27±3.28	0.489	0.000	0.330	0.001

Table 4. Inter-rater reliability testing for both time and sway numbers by the first and second raters

	Intraclass Correlation Coefficient						
	Intraclass Correlation	95% Confidence Interval Lower Bound	Upper Bound	F Test with True Value 0 Value	df1	df2	Sig
Time by first and second raters	0.836	0.760	0.888	6.108	107	107	0.000
Sway number by first and second raters	0.840	0.766	0.891	6.244	107	107	0.000

but there may be some variations in the turning points of the TUG test, where some children made wider turns around the chair, and others made narrower turns (20). The raters stated regarding the PTB test that it was easy to control the children's route as it had a platform. Moreover, since the platform looked the same even though it was made of different materials, this mysterious structure caused motivation in the children according to the statements of the raters. Similarly, a recent paper proposed the use of a red Duplo brick for motivation in the TUG test (21). In general, according to our raters, the PTB test was easy to be understood by children.

The children were asked to walk with one trial test and one real test. In many balance tests (10), three repetitions are allowed for children, and the best result is recorded. On the other hand, the learning effect, which is prominent at younger ages, was avoided in this study with fewer repetitions as this test had sensorial feedback, and it could have been very easy to learn in further repetitions.

The main strength of this paper was the presentation of the psychometric analysis results of a newly designed dynamic balance test, the PTB test, with high test-retest and inter-rater reliability. These findings are likely to encourage the use of this field test to see the balance of pre-schoolers in the conditions of different somatosensory inputs to their feet.

The PTB test offers a simple use with various advantages. First of all, this is the first dynamic balance test which includes different floor materials and creates an advantage to show progression this way. Many professions like physiotherapists, physical educators and occupational therapists can use a progressive procedure for the development of balance by changing the floor material. Thus, this test provides this opportunity. Secondly, since this is low-tech field test, it is a much more inexpensive test than high-tech balance test devices, whereas it is also easy to use this test and make comments on results for users. Thirdly, in this study, there was no risk/injury about the test reported by the raters. Lastly, although the "test" shape was determined as W, the platform can be brought to different shapes like a triangle, a square and a straight line for working on balance (Attachment 1).

Limitations

A limitation of this paper was the need for a gold standard test for balance in preschool children as high-tech/digital devices are required to get more objective results to investigate the validity of the PTB test. Researchers who have training and adequate opportunities in terms of high-tech devices could conduct further studies to investigate the validity of the PTB test for more accurate results (22,23)..

CONCLUSION

In conclusion, the PTB test may be used as a reliable test in clinical practice for pre-school children. Although it is easy to manufacture this test platform, the practitioners who wonder to use this test are suggested to contact the authors to learn more details. Lastly, the psychometrics and clinical utility of the test may also be investigated in older children, or children with developmental delays and special needs in further papers.

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Author contribution: ZGT: Planning, design of platform, interpretation of the results, writing, publication procedures. HH: Design of platform and data collection (rater 2). EÇ: Design of platform and data collection (rater 1). HT: Support to the management of study and writing. TO: Ethical approval and support in data collection. NŞ: Ethical approval and writing. LE: Power Analysis for sample size and support for ethical approval.

Conflict of interests: The authors declare that there was no conflict of interest.

Ethical approval: The study was approved by the Research and Publication Ethics Committee of Eastern Mediterranean University, in accordance with the Declaration of Helsinki (Decision Date: 24.05.2018, No: 2018/59-19).

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